



Miniature Thermal Batteries for Low-Current Applications

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Present Thermal Battery Technology

1. Thermal batteries have been miniaturized for high-current (1 to 4 A/cm²) operation.

- Nuclear applications.
- Missiles.
- Artillery applications (high spin).
- **Volumetric energy density of high spin thermal batteries has been increased by a factor of 8 since FY96 at ARL.**



2. High reliability and mature technology could be applied to low-current operation.



Low-Current Thermal Battery Goals

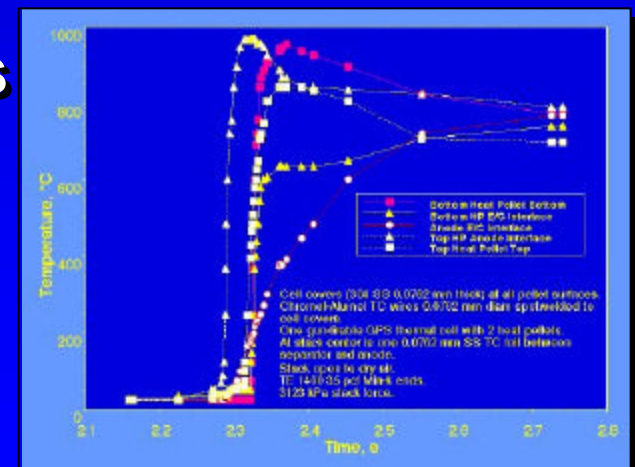


- **Small size.** 0.1 cm^3 – (0.2 in. dia. x 0.2 in. tall)
 0.8 cm^3 – (0.4 in. dia. x 0.4 in. tall)
- **Low current.** (50 μA to 20 μA , 3 to 10 V)
- **Moderate lifetime.** (5 to 10 minutes)
- **High reliability.** (0.9990 at 95% confidence)
- **Long shelf life.** (20 years)



Miniaturization Method

1. Heat transfer is a major problem.
 - High temperature molten salt electrochemistry.
 - Control heat loss rates.
 - Control cell heat generation rates.
2. Optimize a low-current battery design.
 - Calculate thermal lifetime.
 - Operating cell temp. range is 325 to 700° C.
 - Ambient temp. range is -43 to +63° C.
 - 4 thermal cells (7.2 V to 5.4 V at 1.5 mA).





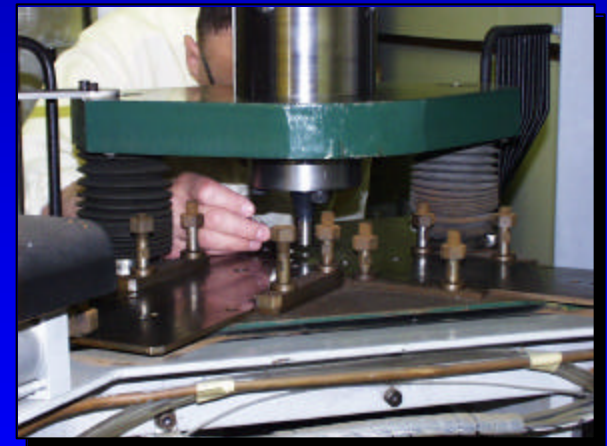
Heat Transfer Considerations

1. Thermal conductivities could be reduced by a factor of 8 in production thermal batteries.

- Improved commercial insulators.
- Improved chemical processing.
- Use of gas gettering agents.

2. Construction improvements facilitate miniaturization.

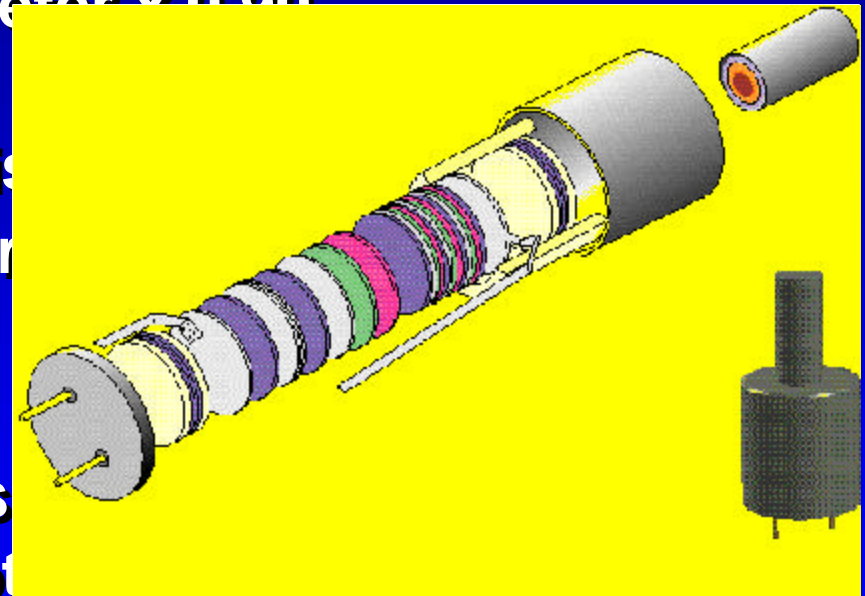
- Single pellet thermal batteries.
- Control of heat generation.
- New electrochemical systems.





Present Miniaturized Thermal Battery

- Volume 9.38 cm³.
 - case is 0.90 inch diameter x 0.90 inch long
 - thermal cell diameter is
- Energy density at 1.5 mA drain 0.090 Wh/l.
 - **320 s thermal lifetime**
- Present battery pellets, gas environment, chemical exothermic reactions.
- Cells contain 72.0 times required electrochemical capacity at 1.5 mA drain.





Miniaturized Thermal Battery (2 to 5 Years)

- Volume 0.552 cm³.
 - case is 0.35 inch diameter x 0.35 inch long
 - thermal cell diameter is 0.2 inch
- Energy density 1.61 Wh/l at 1.5 mA drain.
 - **338 s thermal lifetime**
- Multi-pellet construction, improved gas environment from improved chemical processing, some gas gettering.
- Cells contain 3.41 times required electrochemical capacity at 1.5 mA drain.



Miniaturized Thermal Battery (5 to 10 Years)

- Volume 0.129 cm³.
 - case is 0.20 inch diameter x 0.25 inch long
 - thermal cell diameter is 0.12 inch
- Energy density 11.5 Wh/l at 1.5 mA drain.
 - **566 s thermal lifetime**
- Single pellet battery construction, improved chemical processing and gas gettering, along with increased internal heat generation.
- Cells contain 1.10 times required electrochemical capacity at 1.5 mA drain.



Energy and Power Densities

	Present Thermal	Thermal 2 to 5 Years	Thermal 5 to 10 Years	Present SDF Battery
Wh/l	0.090	1.61	11.5	0.744
Wh/kg	0.061	0.738	4.19	0.159
W/l	1.01	17.1	73.4	9.92
W/kg	0.685	7.85	26.6	2.11
cm ³	9.38	0.552	0.129	0.128

Thermals operate at 7.2 to 5.4 V and 1.5 mA.



Lifetime and Pulse Characteristics

	Present Thermal	Thermal 2 to 5 Years	Thermal 5 to 10 Years	Present SDF Battery
Life (s)	320	338	566	270
Pulse (kW/l)	2.10	8.97	13.8	0.027
Over-design (Ratio)	72.0	3.41	1.10	

Thermals operate at 7.2 to 5.4 V and 1.5 mA.



Thermal Battery Starters Require Miniaturization

1. Inertial White starter is 0.312 inch diameter x 1.05 inch long (**1.32 cm³** and 6.5 g).
2. Inertial M42 C-1 primer is 0.175 inch diameter x 0.120 inch long (**0.0473 cm³** and 0.20 g).
3. Inertial M42 C-1 primer starter is similar in size and mass to the White starter. **One primer starter might be used for several inertial primers.**
4. Electrical squib is 0.205 inch diameter x 0.185 inch long (**0.100 cm³** and 0.56 g).





Conclusions

- 1. Small thermal batteries can be made the size of present thermal battery squib initiators.**
- 2. Thermal batteries the size of present squib initiators can operate for several minutes at μA and mA current drains.**
- 3. Low-current thermal batteries can be used in miniaturized fuzes where they can supply large pulse currents.**